TITLE:

Vortex Core of Chiral p-wave Superconductors(New Developments in Strongly Correlated Electron Systems)

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CITATION:

Kato, Yusuke. Vortex Core of Chiral p-wave Superconductors(New Developments in Strongly Correlated Electron Systems). 物性研究 2001, 76(5): 688-688

ISSUE DATE:

2001-08-20

URL:

http://hdl.handle.net/2433/97046

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Vortex Core of Chiral p-wave Superconductors

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In the presence of a single vortex, the Cooper-pairs have an angular momentum ("vorticity")$L^{\rm c} = \pm 1$ in its *center-of-mass motion* around the vortex. In the chiral p-wave superconductors, on the other hand, the Cooper-pairs have a definite angular momentum ("chirality") $L^{\rm r} = \pm 1$ in its *relative motion* even in the absence of vortices. The interplay between the vorticity and chirality makes the physics of chiral p-wave vortex intriguing.

The present author and N. Hayashi[1] performed self-consistent numerical calculations of the pair-potential and the supercurrent density around a single vortex of chiral p-wave superconductors. We also studied these two quantities analytically with the use of "single branch approximation" where only the chiral branch of Andreev bound states are taken into account in the gap equation. Numerical and analytical results show a good agreement at low temperatures near the core region. We also found that the size of vortex core shrinks with temperature decreasing ("Kramer-Pesch effect") in chiral p-wave superconductors.

Further we estimated the impurity scattering rate of quasiparticles in the self-consistently determined pair-potential of chiral p-wave vortex within the single branch approximation. We found that the results are essentially the same as my previous results[2]; the impurity scattering rate is appreciably suppressed in the case where $L^{\rm tot} \equiv L^{\rm c} + L^{\rm r} = 0$. For the scattering rate, the total angular momentum $L^{\rm tot}$ is crucial. Accordingly, the impurity effect in chiral p-wave vortex with $L^{\rm tot} = 0$ is similar to that in the s-wave superconductors without vortices. Thus, the suppression of the impurity scattering rate in chiral p-wave vortex with $L^{\rm tot} = 0$ results from *the Anderson theorem within vortex cores.*

Many experimental efforts have been done to observe the shrinkage of vortex core ever since Kramer and Pesch pointed it out in 1974. The impurity effect in vortex cores, however, smears out this effect even in the moderately clean superconductors. Owing to the suppression of the scattering rate in vortex core, the chiral p-wave vortex serves a unique chance of the observation of the Kramer-Pesch effect in experiments.

Furthermore, novel impurity effects in vortex cores of chiral p-wave superconductors can be seen also in the calculation of pinning energy at low temperatures[3].

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